CHAOS - Configurations Analysis of Swarms of Cyber-Physical Systems

Valeria Trombetta[1], Maxime Cordy[1], Enrico Tronci[2] and Axel Legay[3]

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[1] University of Luxembourg, (SnT)
[2] Sapienza University of Rome - Italy
[3] Catholic University of Louvain - Belgium

UNIVERSITY OF LUXEMBOURG

Introduction and Motivation (1 / 6)

- Cyber-Physical Systems (CPS)
- Simulations of CPS
- Noises & Disturbances (N&D)
- Variability in CPS

Introduction and Motivation (2 / 6)

Variability in CPS

- Variety of contexts
  - ❖ Environmental conditions
  - ❖ New costumer requirements

The main issue

- Develop new variants is expensive

Introduction and Motivation (3 / 6)

The approach

- Injection of variation points
  - ❖ Variability-Intensive Systems (VIS)

VIS as a large class system

- Software Product Lines
  - ❖ Variation points as *Features*
- Configurable Systems
  - ❖ Variation Points as *Configuration Parameters*

Introduction and Motivation (4 / 6)

The concept of Variability

- Each fashion in which the variants are not equal
  - ❖ Different values for a variable

The purpose

- Get a variant that satisfy the requirements
  - ❖ With the highest probability
  - ❖ In the majority of contexts

Introduction and Motivation (5 / 6)

The problems of Variability

- Get the appropriate variant is not trivial
  - ❖ The variability affects the system behavior
  - ❖ It can lead to an exponential computation
  - ❖ Multiple criteria and constraints in case of multi-domain VIS
  - ❖ Uncertainties (N&D) can trigger unpredictable behavior of the system

Introduction and Motivation (6 / 6)

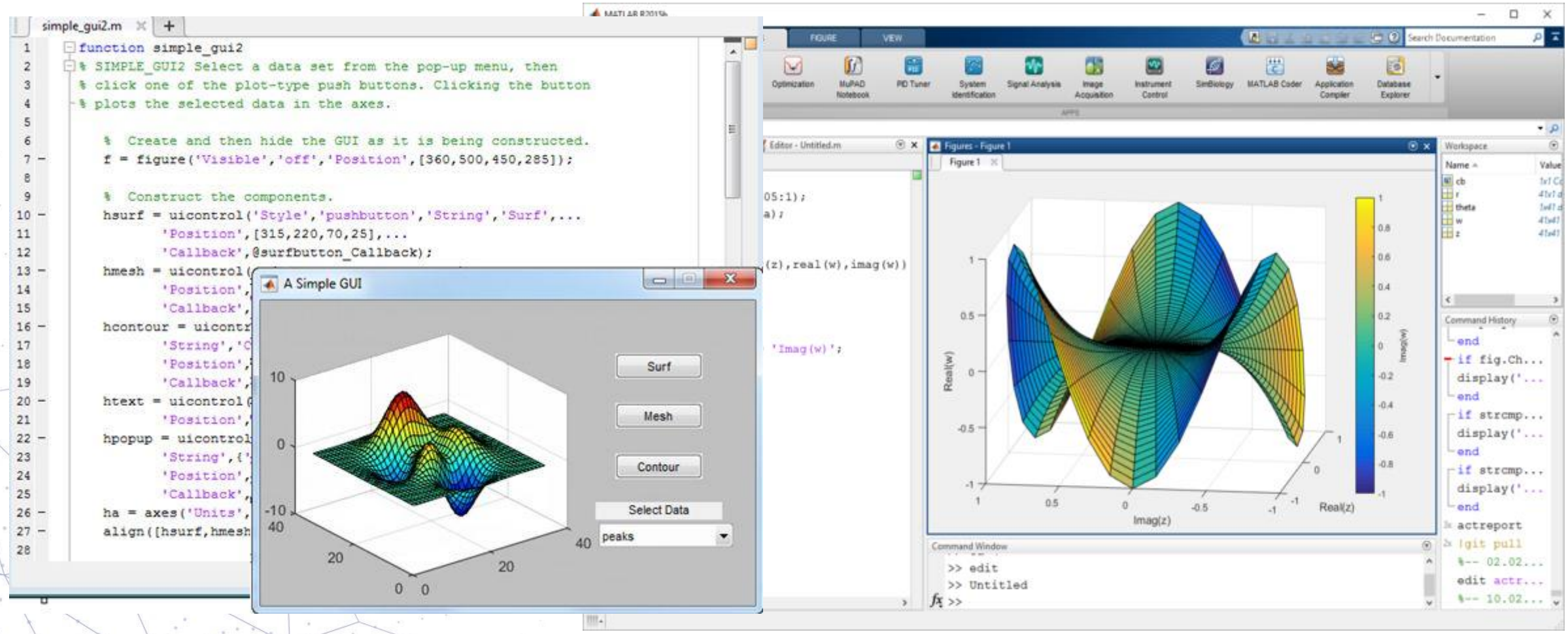
VIS Variability

- Design-Time
  - ❖ Requirements have been a-priori defined
  - ❖ The aim is to discover which variants are more likely to satisfy the requirements
- Run-Time
  - ❖ A variant is already running and it is faced to uncertainties
  - ❖ The goal is to switch to another variant to ensure that requirements are still satisfied

Main purposes of the project (1 / 1)

- help engineers to explore all the possible and appropriate design alternatives wrt:
  - ❖ the scenario
  - ❖ the mission
  - ❖ the budget
- Evaluate which kind of variable had a major impact on the configuration
- Identify which uncertainties affected the system at most
- Explore the state space
- Provide an easy-reusable and extendable tool
- A realistic case-study entirely customizable

Framework (1 / 1)



Case- Study (1 / 1)

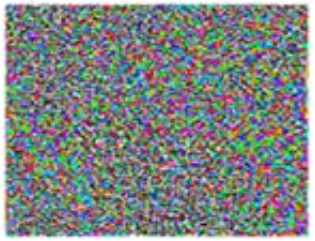
Swarm of Drones

- Drones Features
  - ❖ Battery (H-M-L)
  - ❖ Radio (H-M-L)
    - ➢ TX
    - ➢ RX

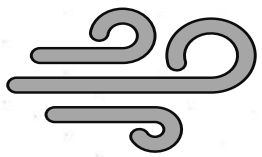
- Drones Characteristics
  - ❖ Anti-collisions
  - ❖ Same velocity
  - ❖ Constraints on spawn point and locations
    - ➢ Wrt the target and obstacles
    - ➢ Wrt the swarm

Uncertainties (1 / 1)

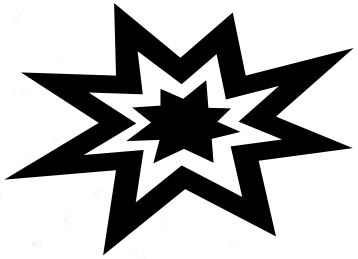
- Noises

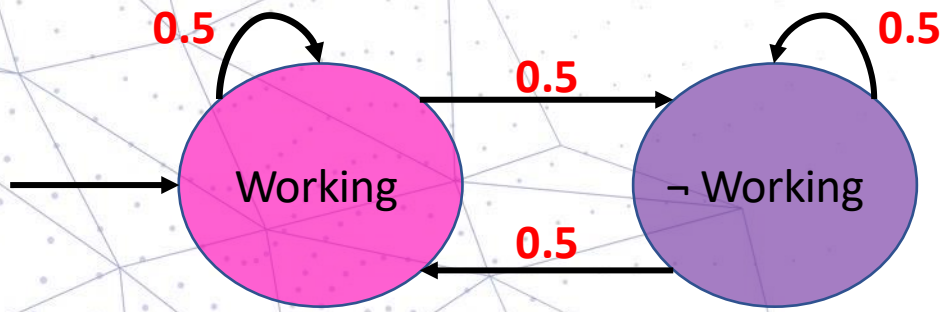


- Gusts

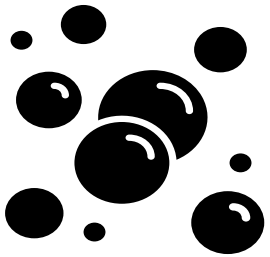


- Faults
  - ❖ Markov Chain



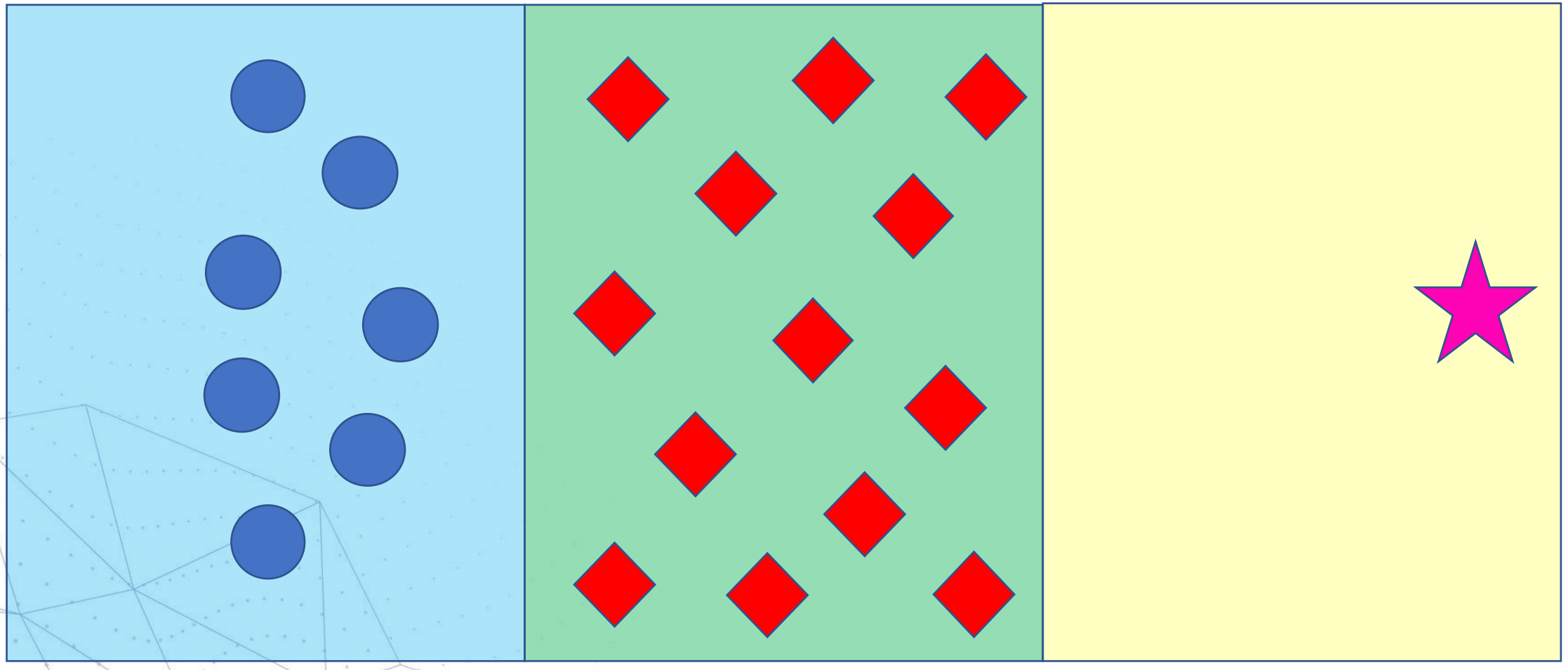


- Obsctacles
  - ❖ Constraints on spawn point (like drones)
  - ❖ Anti-collision (like drones)
  - ❖ Absent
  - ❖ Present
    - ➢ Fixed
    - ➢ Moving (Random Motion)



- Target
  - ❖ Unique & always present
  - ❖ Fixed or Moving (Random Motion)
  - ❖ Constraints on spawn point

A general example of scenario (1 / 1)



= DRONE

= OBSTACLE

= TARGET

Research Questions (1 / 3)

RQ1: Given a scenario, is it fundamental to monitor the effect of variability even in small systems?
ARQ1: Yes, even in small systems like drones which in our case study have only 2 features, especially when in the swarm there are few drones.

RQ2: What is the total size of configuration space composed by multiple small configuration systems and their scenarios?
ARQ2: The total size of configuration space is 12264

RQ3: Can we reduce this complex configuration space to a smaller step of solutions?
ARQ3: Yes, but the only if the drones are all identical (e.g. top quality ones)

Research Questions (2 / 3)

RQ4: Do the identified best configurations remain valid in the presence of uncertainties?
ARQ4: Yes, they change only in case of gusts (better quality drones) or mobile target (extra drones).

RQ5: Given a set of scenarios, can we identify the optimal configuration wrt the budget and the desired assurance level?
ARQ5: We identified a set of configuration that over the 12264 analyzed, assures a probability of success of 96% minimizing the expenditure of the budget.

RQ6: Do the identified configurations remain valid taking into account both the design-time and run-time variability?
ARQ6: [In a development phase]

Research Questions (3 / 3)

RQ7: Given a set of scenarios, an assurance level, a budget whose expenditure must be minimised, is the identified configuration the same for both design and run-time?
ARQ7: [In a development phase]

RQ8: Is it feasible to develop an approach to reduce the computational time related to the simulations?
ARQ8: [In a development phase]

Future Directions (1 / 1)

- Validate the approach with further models also belonging to further domains, multi-target setting, and different scenarios (e.g. military ones with attacking drones/obstacles/target).
- Adopt different kind of uncertainties.
- Insert a leader in the Swarm for reconfiguration purposes.
- **ARQ6** Preliminary experiments have shown that given a budget and a level of assurance it is possible to find the optimal configuration wrt all of these.
- **ARQ8** It is under development an approach based on simulation snapshots.
- Answer **RQ1**, **RQ2**, **RQ3** and **RQ7** by performing experiments considering various specific safety industrial standards, additional missions and scenarios, by testing the validity to handle variability at design-time and run-time.

Thanks for your attention.